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Outcomes of Lung Transplantation for Bronchiolitis Obliterans after Hematopoietic Stem Cell Transplantation Compared with Those for Idiopathic Pulmonary Fibrosis

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Purpose: Bronchiolitis obliterans syndrome (BOS) can develop as a manifestation of graft-versus-host disease following allogeneic hematopoietic stem cell transplantation (allo-HSCT), and may ultimately require lung transplantation (LT). However, reports on LT outcomes for BOS after allo-HSCT are limited. This study aimed to compare the outcomes of LT for BOS following allo-HSCT with those for idiopathic pulmonary fibrosis (IPF).

Materials and Methods: A total of 487 patients underwent LT between January 2010 and August 2023. Among them, the baseline characteristics and outcomes of 35 patients with BOS following allo-HSCT and 216 patients with IPF were analyzed.

Results: The BOS group was younger and had a lower body mass index (BMI) compared to the IPF group (33.7±11.9 years vs. 59.7±7.3 years, $p<0.001$; 17.6±3.7 kg/m^2 vs. 22.0±3.6 kg/m^2, $p<0.001$, respectively). The proportion of male patients was lower in the BOS group than in the IPF group (54.3% vs. 84.3%, $p<0.001$). Preoperative ventilator support was more common in the BOS group compared to the IPF group (62.9% vs. 32.4%, $p=0.001$). In Kaplan–Meier survival analysis, the 5-year survival rate was significantly higher in the BOS group than in the IPF group (71.0% vs. 44.9%, $p=0.022$). In the Cox proportional hazards model, age was the only factor significantly associated with survival [hazard ratio (95% confidence interval): 1.04 (1.02–1.07), $p<0.001$].

Conclusion: The survival rate of the BOS group was not inferior to that of the IPF group after adjusting for sex, age, and BMI. Therefore, LT should be actively considered as a treatment option for patients with BOS following allo-HSCT.

Key Words: Lung transplantation, bronchiolitis obliterans syndrome, late onset non-infectious pulmonary complication, allogeneic hematopoietic stem cell transplantation, graft-versus-host disease, survival

INTRODUCTION

Allogeneic hematopoietic stem cell transplantation (allo-HSCT) is an established treatment for various hematological malignancies. Although survival rates after allo-HSCT for hematologic diseases have improved, allo-HSCT can also lead to serious complications, such as graft-versus-host disease (GVHD).[1] GVHD can involve multiple organs, including the skin, gastrointestinal tract, liver, and lung, and is classified according to the severity and extent of involvement.[2] Pulmonary GVHD is particularly associated with morbidity and mortality in allo-HSCT

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recipients; it is classified into infectious and non-infectious forms.[3] With improvements in infection management, the relative importance of late-onset non-infectious conditions (LONPIC) has increased. Among these, bronchiolitis obliterans syndrome (BOS) is the most common manifestation.[4]

BOS affects 4%–5% of allo-HSCT recipients and up to 15% of those who develop chronic GVHD.[5-7] Despite recent advancements in immunosuppressive therapy, the prognosis of BOS following allo-HSCT remains poor. Lung transplantation (LT) has emerged as a potential definitive treatment for BOS following allo-HSCT, with some studies reporting encouraging outcomes. However, comprehensive analyses are limited due to the rarity of the disease and the small number of reported cases.[4,8-13]

This study aimed to investigate the characteristics and outcomes of patients who underwent LT for BOS following allo-HSCT. In addition, we compared these patients with those who received LT for idiopathic pulmonary fibrosis (IPF), the most common indication for LT, to characterize the clinical features and survival outcomes of the BOS group.

MATERIALS AND METHODS

Patients

Between January 2010 and August 2023, 487 patients underwent LT at a single institution. Based on the preoperative diagnosis, patients were categorized into two groups: 35 with BOS following allo-HSCT and 216 with IPF. This study was approved by the Institutional Review Board (IRB No. 2024-1537-001), and the requirement for informed consent was waived due to its retrospective design.

Data acquisition

Basic demographic and clinical characteristics were retrospectively reviewed using patient medical records. The diagnosis of BOS was confirmed according to the 2014 National Institutes of Health consensus clinical criteria.[2] Extensive GVHD was defined as involvement of organs other than the lungs and skin. Severe adhesion was defined as a case in which either lung exhibited marked pleural adhesion. Ischemic time was defined as the interval between donor aortic cross-clamping and completion of pulmonary anastomosis. Postoperative bleeding was defined as either a total chest tube drainage volume >1000 mL within 24 hours or the need for reoperation due to bleeding. Primary graft dysfunction (PGD) grade was assessed according to the International Society for Heart and Lung Transplantation (ISHLT) guidelines, and the proportion of patients with grade 3 PGD (PGD G3) was recorded.[14] Pulmonary function tests (PFTs) were routinely performed at 1, 3, 6, and 12 months post-transplantation.

Statistical analysis

Continuous variables are presented as mean±standard deviation and were analyzed using independent-sample t-tests. Categorical variables are presented as numbers and percentages and were analyzed using the chi-square test. Survival analysis was performed using Kaplan–Meier survival curves and Cox proportional hazards regression models. A p-value<0.05 was considered statistically significant. All analyses were conducted using RStudio version 1.4.555 and SPSS version 27.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Basic demographic and clinical characteristics

Pre-transplant characteristics of patients with BOS following allo-HSCT are summarized in Table 1. The mean age at the time of allo-HSCT was 27.4 years, and acute myeloid leukemia was the most common indication for transplantation (n=15, 43.3%). Extensive GVHD was observed in 65.7% of patients (n=23). The median interval from allo-HSCT to the diagnosis of BOS was 16 months, and the median interval from BOS to LT was 26 months.

Table 1. Pre-Transplant Characteristics of Patients with BOS Following Allo-HSCT (n=35)

	Value
Age at time of allo-HSCT (yr)	27.4±10.5
Preoperative FEV_1	1.33±0.52 (L), 45.1±16.7 (%)
Preoperative FVC	1.65±0.60 (L), 42.1±13.5 (%)
Preoperative FEV_1/FVC (%)	83.08±17.6
Indication for HSCT (%)	
SAA	5 (14.3)
AML	15 (43.3)
ALL	11 (31.4)
Others	CML (1), MDS (1), PTCL (1), DLBCL (1)
Type of HSCT	
R-BMT	7 (20.0)
R-PBSCT	12 (34.3)
UR-BMT	3 (8.6)
UR-PBSCT	13 (37.1)
Chronic GVHD	
Lung alone	9 (25.7)
Skin and lung involved	3 (8.5)
Extensive	23 (65.7)
Interval (HSCT to BOS), months	16 (4–180)
Interval (BOS to LT), months	26 (2–140)

BOS, bronchiolitis obliterans syndrome; allo-HSCT, allogeneic hematopoietic stem cell transplantation; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; SAA, severe aplastic anemia; AML, acute myeloid leukemia; ALL, acute lymphoblastic leukemia; CML, chronic myeloid leukemia; MDS, myelodysplastic syndrome; PTCL, peripheral T-cell lymphoma; DLBCL, diffuse large B-cell lymphoma; R-BMT, related donor bone marrow transplantation; UR-PBSCT, unrelated donor peripheral blood stem cell transplantation; GVHD, graft-versus-host disease; LT, lung transplantation.
Data are presented as mean±standard deviation or n (%).

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LT characteristics for patients with BOS following allo-HSCT and those with IPF are presented in Table 2. Patients with BOS were significantly younger than those with IPF (33.7 years vs. 59.7 years, $p<0.001$) and had a lower proportion of male patients (54.3% vs. 84.3%, $p<0.001$). Compared to patients with IPF, those with BOS had a lower body mass index (BMI) (17.6 kg/m^2 vs. 22.0 kg/m^2, $p<0.001$) and were more likely to require ventilator support prior to LT (62.9% vs. 32.4%, $p=0.001$). Preoperative laboratory findings revealed that BOS patients had significantly higher serum albumin levels compared to IPF patients (3.7 g/dL vs. 3.4 g/dL, $p=0.014$). No significant differences were observed in other preoperative characteristics, intraoperative findings, or postoperative complications between the two groups.

Survival analysis in the BOS following allo-HSCT group

Kaplan–Meier survival analyses were performed based on stem cell source, donor type, HSCT indication, and GVHD extent. Survival analysis according to stem cell source [bone marrow transplantation (BMT) vs. peripheral blood stem cell transplantation (PBSCT)] demonstrated a significant difference (log-rank test, $p=0.012$) (Fig. 1A). In contrast, donor type, interval between HSCT and LT, and GVHD extent were not significantly associated with survival (Fig. 1B-D).

Table 2. Comparison of Lung Transplantation Characteristics between Patients with BOS Following Allo-HSCT and Those with IPF

	BOS following HSCT (n=35)	IPF (n=216)	*p*
Age (yr)	33.7±11.9	59.7±7.3	<0.001*
Sex, male	19 (54.3)	182 (84.3)	<0.001*
BMI (kg/m^2)	17.6±3.7	22.0±3.6	<0.001*
Preoperative ventilator	22 (62.9)	70 (32.4)	0.001*
Preoperative ECMO	7 (20.0)	71 (32.9)	0.168
Albumin (g/dL)	3.7±0.69	3.4±0.67	0.014*
Total protein (g/dL)	6.0±0.94	6.3±1.22	0.132
Severe pleural adhesion	18 (51.4)	100 (50.0)	0.876
Ischemic time (min)	246.6±79.9	226.2±74.3	0.140
Contra-ischemic time (min)	335.3±90.2	321.4±75.7	0.334
Intraoperative blood loss (cc)	2771.4±2302	3028.0±2617	0.587
Total operation time (min)	391.8±95.9	390.1±83.6	0.916
Dialysis	5 (14.3)	38 (18.5)	0.544
Postoperative bleeding	7 (20.0)	41 (20.1)	0.989
PGD G3 T0	15 (42.9)	111 (55.5)	0.166
PGD G3 T24	11 (31.4)	74 (37.0)	0.527
PGD G3 T48	6 (17.1)	56 (28.0)	0.179
PGD G3 T72	6 (17.1)	39 (19.5)	0.744
ICU stay (day)	10.2±12.9	9.2±7.9	0.663
Donor age (yr)	43.5±12.4	43.8±12.7	0.895
Donor sex, male	26 (74.3)	148 (67.0)	0.392
Donor PaO_2/FiO_2 ratio	464.4±98.3	452.6±92.2	0.491

BOS, bronchiolitis obliterans syndrome; allo-HSCT, allogeneic hematopoietic stem cell transplantation; IPF, idiopathic pulmonary fibrosis; BMI, body mass index; ECMO, extracorporeal membrane oxygenation; PGD G3, primary graft dysfunction grade 3; T0, immediate postoperative; T24, postoperative 24 hours; T48, postoperative 48 hours; T72, postoperative 72 hours; ICU, intensive care unit.
Data are presented as mean±standard deviation or n (%).
*$p<0.05$.

Survival analysis and Cox proportional hazard model between BOS following allo-HSCT and IPF

The Kaplan–Meier survival curve demonstrated a significant difference between the groups (log-rank test, $p=0.022$) (Fig. 2). The 5-year survival rates for BOS following allo-HSCT and IPF were 71.0% and 44.9%, respectively. The survival rate of the BOS group was comparable to that of all lung transplant recipients aged <60 years in the ISHLT registry.[15]

A Cox proportional hazards model was constructed, adjusting for age, sex, BMI, and diagnosis group. Age was identified as a significant factor affecting survival {hazard ratio (HR) [95% confidence interval (CI)]: 1.04 (1.02–1.07), $p<0.001$} (Fig. 3). The diagnosis group (BOS vs. IPF) was not significantly associated with survival [HR (95% CI): 0.69 (0.29–1.62), $p=0.4$].

PFTs after LT between groups

During the 12-month follow-up period, both forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV_1) improved in the BOS and IPF groups (Fig. 4). Preoperatively, the FVC was 1.65 L (42.1%) in the BOS group and 1.71 L (44.3%) in the IPF group, while the FEV_1 was 1.33 L (45.1%) and 1.26 L (43.2%), respectively. At 1 month postoperatively, the FVC increased to 1.90 L (42.1%) in the BOS group and 2.11 L (54.0%) in the IPF group, and the FEV_1 increased to 1.72 L (60.4%) and 1.87 L (63.2%), respectively. At 3 months postoperatively, the FVC was 2.03 L (52.1%) in the BOS group and 2.17 L (56.4%) in the IPF group, while the FEV_1 was 1.75 L (59.7%) and 1.86 L (63.0%), respectively. At 6 months, the FVC was 2.25 L (58.9%) and 2.32 L (59.7%), and the FEV_1 was 1.86 L (64.3%) and 1.94 L (65.0%) in the BOS and IPF groups, respectively. At 12 months, the FVC was 2.59 L (64.4%) in the BOS group and 2.48 L (63.7%) in the IPF group, and the FEV_1 was 2.14 L (70.4%) and 2.03 L (67.5%), respectively. No significant differences in FVC or FEV_1 were observed between the two groups at any time point.

DISCUSSION

In this study, we compared patients who underwent LT for BOS following allo-HSCT with those who underwent LT for IPF. Among patients with BOS, the stem cell source was significantly associated with survival outcomes, with a 5-year survival rate of 84.0% for PBSCT recipients and 50.0% for BMT recipients ($p=0.012$). When comparing the BOS and IPF groups, significant differences were observed in sex distribution, age, BMI, preoperative serum albumin levels, and the need for preoperative ventilator support. Kaplan–Meier survival analysis demonstrated superior survival in the BOS group compared to the

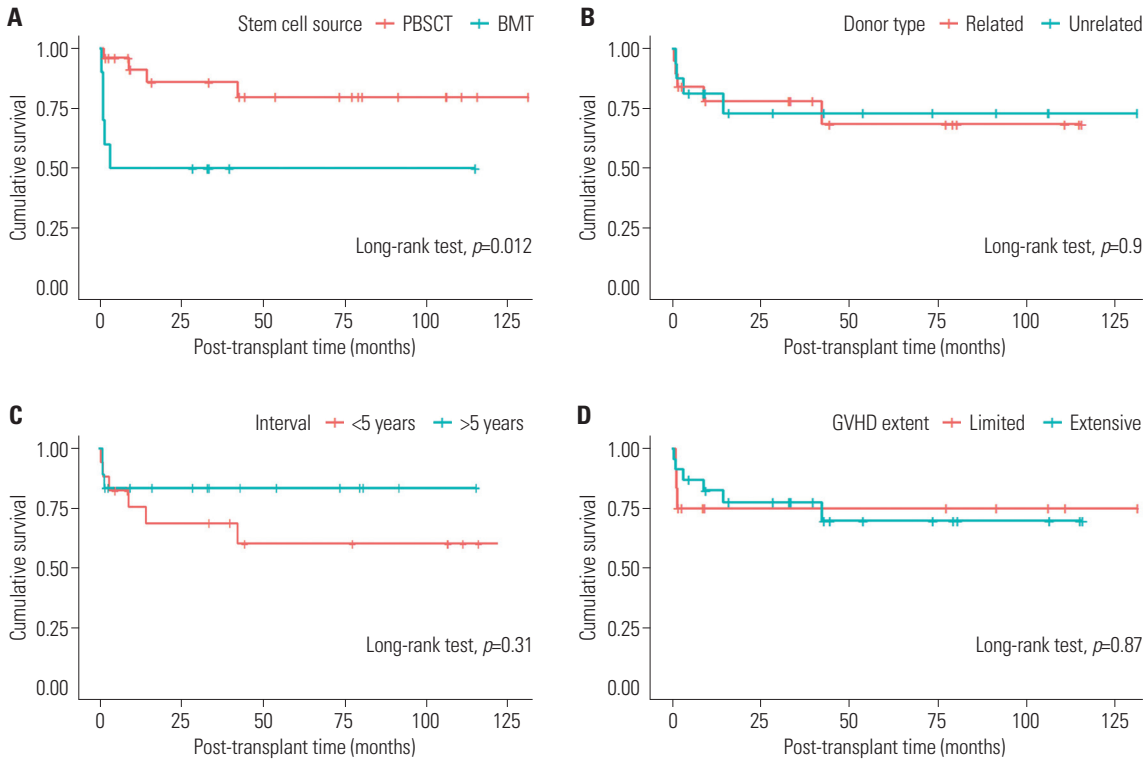

Fig. 1. Kaplan–Meier survival curves in the BOS group. (A) Survival according to stem cell source (BMT vs. PBSCT). (B) Survival according to donor type (related vs. unrelated). (C) Survival according to the interval between HSCT and LT. (D) Survival according to GVHD extent (limited vs. extensive). PBSCT, peripheral blood stem cell transplantation; BMT, bone marrow transplantation; GVHD, graft-versus-host disease; BOS, bronchiolitis obliterans syndrome; HSCT, hematopoietic stem cell transplantation; LT, lung transplantation.

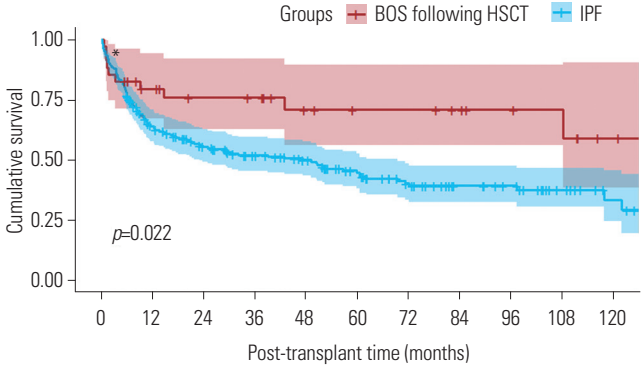

Fig. 2. Kaplan–Meier survival curves comparing the BOS and IPF groups. The log-rank test indicated a significant difference (p=0.022). BOS, bronchiolitis obliterans syndrome; HSCT, hematopoietic stem cell transplantation; IPF, idiopathic pulmonary fibrosis.

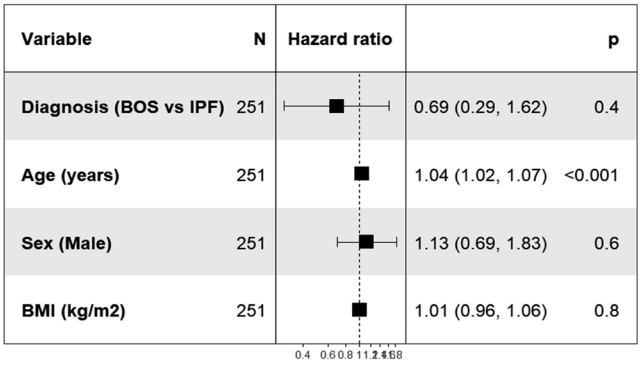

Fig. 3. Cox proportional hazards analysis in the BOS and IPF groups. The model was adjusted for age, sex, BMI, and diagnosis. BOS, bronchiolitis obliterans syndrome; IPF, idiopathic pulmonary fibrosis; BMI, body mass index.

IPF group (5-year survival: 71.0% vs. 44.9%, p=0.022). However, after adjusting for age, BMI, and sex using a Cox proportional hazards model, no significant difference in survival was observed between the groups [HR (95% CI): 0.69 (0.29–1.62), p=0.4]. Although no significant difference was found between the two groups in terms of pulmonary function, both FVC and FEV_1 consistently improved over the 12-month postoperative follow-up period.

Among patients with BOS, the PBSCT group showed a higher survival rate compared to the BMT group (Fig. 1A). To explore potential reasons for this difference, a subgroup analysis was conducted comparing PBSCT and BMT recipients. Postoperative bleeding was more frequent in the BMT group (p=0.012). A previous study reported that BMT recipients experienced delayed platelet recovery and greater transfusion requirements during the early post-transplant period, which may have contributed to the increased risk of postoperative bleeding.[16] To the best of our knowledge, no other studies have spe-

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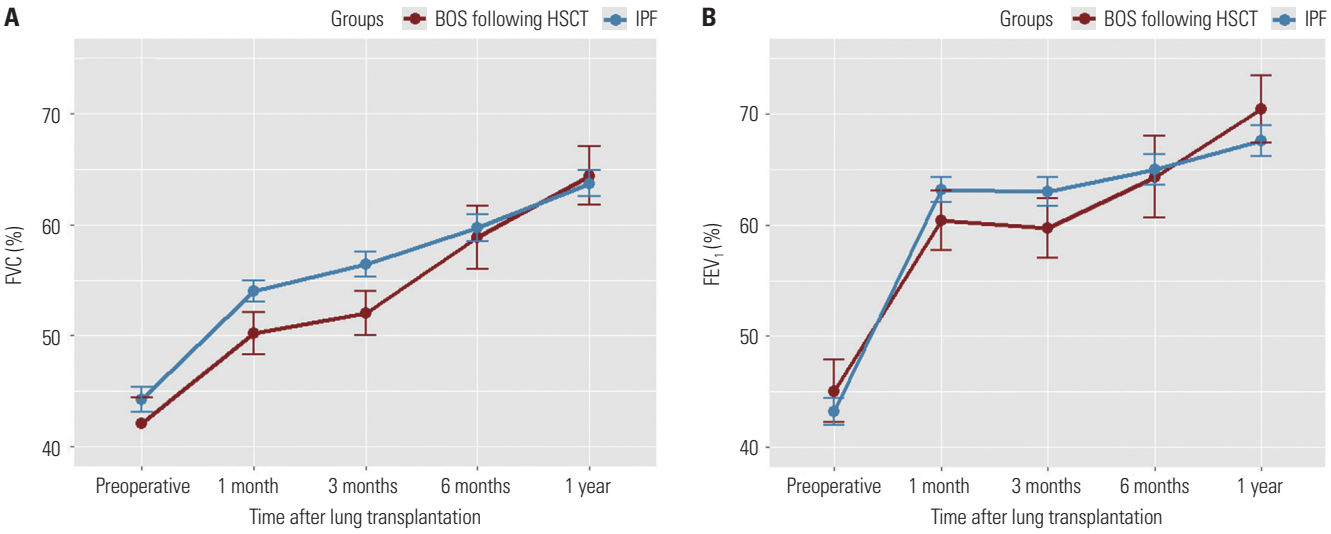

Fig. 4. Pulmonary function test results during the postoperative follow-up period in the BOS and IPF groups. (A) Relationship between the percentage of predicted FVC and time. (B) Relationship between the absolute value of FEV_1 and time. BOS, bronchiolitis obliterans syndrome; HSCT, hematopoietic stem cell transplantation; IPF, idiopathic pulmonary fibrosis; FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 second.

cifically evaluated LT outcomes based on stem cell source. Although a meta-analysis of survival after HSCT showed no significant survival difference between PBSCT and BMT, a separate study investigating risk factors for BOS found that PBSCT recipients had a higher incidence of BOS compared to those who received related BMT.[17,18] Other factors, including donor type, transplantation interval, and GVHD extent, were not associated with differences in survival.

The optimal timing for LT after allo-HSCT remains controversial due to the risk of relapse of the primary hematologic malignancy. The ISHLT guidelines recommend avoiding LT within 2 years of HSCT and suggest considering it after approximately 5 years.[19] In a meta-analysis with a 60-month follow-up, patients with an interval >60 months between HSCT and LT showed a trend toward improved survival (p=0.065).[4] In the present study, only 2 patients (5.7%) underwent LT within 24 months after HSCT; therefore, survival analysis for this subgroup was not performed. Additionally, 17 of 35 patients (48.5%) underwent LT within 60 months of HSCT; however, Kaplan–Meier analysis revealed no significant difference in survival based on this interval (log-rank test, p=0.31) (Fig. 1C). One patient in this study exhibited clinical findings suggestive of recurrence of hematologic malignancy 10 years after LT; however, a definitive evaluation was not possible due to the patient's deteriorating condition.

To investigate the characteristics of BOS following allo-HSCT, a comparative analysis was conducted with patients diagnosed with IPF, the most common indication for LT in Korea.[20] Compared to the IPF group, patients in the BOS group were younger, had a lower proportion of males, a lower BMI, and a higher rate of preoperative ventilator support. Given the lower BMI and greater need for preoperative ventilator care, poorer postoperative rehabilitation and pulmonary function were anticipated; however, follow-up PFTs and other postoperative outcomes did not differ significantly from those of the IPF group (Table 2 and Fig. 4).[21,22] This may be attributed to the younger age and higher serum albumin levels of the BOS group, which may have offset the anticipated negative factors.[23]

The Kaplan–Meier survival curve demonstrated a significant difference between the groups, with 5-year survival rates of 71.0% for BOS following allo-HSCT and 44.9% for IPF (p=0.022) (Fig. 2). Although some heterogeneity was present, previous meta-analyses have reported survival rates of BOS following allo-HSCT similar to those in our study. However, these meta-analyses found no significant difference in survival between the BOS and fibrosis groups, and another study reported comparable survival outcomes between BOS following allo-HSCT and other disease entities.[4,24] In our analysis, despite an observed difference in unadjusted survival rates, no significant difference was found between BOS and IPF in the Cox proportional hazards model after adjusting for age, sex, and BMI [HR (95% CI): 0.69 (0.29–1.62), p=0.4]. Given the younger average age and non-inferior survival outcomes of the BOS group compared to the IPF group, LT should be actively considered in eligible BOS patients.

In this study, a total of nine patients in the BOS group died, six of whom died within 90 days postoperatively. The 90-day postoperative mortality rate in the BOS group was 17.1%, which is higher than the generally reported rate of approximately 10%.[25] The remaining three patients died of infections at 9, 14, and 42 months after transplantation. When comparing the mortality and survival groups, ischemic time was significantly shorter in the survival group (225.8±74 minutes vs. 299.9±64 minutes, p=0.012).

This study has several limitations. BOS and IPF are inherently distinct disease entities; BOS shares more pathophysiological characteristics with obstructive lung diseases such as COPD.

However, in our country, COPD accounts for only a small proportion of indications for LT. Although cystic fibrosis (CF) patients are similar in age to those with BOS, CF is extremely rare in Korea, making direct comparison infeasible. We also considered comparing BOS following allo-HSCT with BOS occurring after LT; however, the number of such cases was small and involved retransplantation, limiting the feasibility of analysis. IPF was therefore selected as the comparator group, as it represents the most common indication for LT in Korea.

We attempted to perform propensity score matching to adjust for age and sex, but only 12 matched patients remained, making comparative analysis inappropriate. Instead, we conducted a multivariable survival analysis using a Cox proportional hazards model adjusted for age, sex, and BMI, which showed no significant difference in survival between disease groups [HR (95% CI): 0.69 (0.29–1.62), p=0.4].

This was a retrospective observational study with a small sample size from a single center; therefore, the results should be interpreted with caution. Additionally, 2 patients (5.7%) did not meet the 24-month interval between HSCT and LT recommended by the ISHLT guidelines, precluding subgroup analysis. Future studies with a larger cohort may allow for a more detailed investigation of this issue.

In conclusion, compared with patients with IPF, those with BOS were younger, had a lower BMI, were more likely to be female, and more frequently required preoperative ventilator support. The BOS group demonstrated superior survival compared to the IPF group, with comparable outcomes observed after adjustment for age, sex, and BMI. These findings suggest that LT should be actively considered as a treatment option for patients with BOS following allo-HSCT. Although the results of this study may inform clinical decision-making for this patient population, multicenter studies with larger cohorts are warranted to validate and strengthen these findings.

AUTHOR CONTRIBUTIONS

Conceptualization: Jin Gu Lee. Data curation: Ha Eun Kim, Young Ho Yang, A La Woo, Eun Young Kim, Moo Suk Park, and Song Yee Kim. Formal analysis: Bong Suk Park and Jin Gu Lee. Investigation: Bong Suk Park. Methodology: Dae Joon Kim, Chang Young Lee, Byung Jo Park, and Jin Gu Lee. Project administration: Jin Gu Lee. Resources: Ha Eun Kim, Young Ho Yang, A La Woo, Eun Young Kim, Moo Suk Park, and Song Yee Kim. Software: Bong Suk Park. Supervision: Dae Joon Kim, Chang Young Lee, Byung Jo Park, and Jin Gu Lee. Validation: Dae Joon Kim, Chang Young Lee, Byung Jo Park, and Jin Gu Lee. Visualization: Bong Suk Park. Writing—original draft: Bong Suk Park. Writing—review & editing: Ha Eun Kim, Young Ho Yang, Dae Joon Kim, Chang Young Lee, and Byung Jo Park. Approval of final manuscript: all authors.

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REFERENCES

1. Gooley TA, Chien JW, Pergam SA, Hingorani S, Sorror ML, Boeckh M, et al. Reduced mortality after allogeneic hematopoietic-cell transplantation. N Engl J Med 2010;363:2091-101.
2. Jagasia MH, Greinix HT, Arora M, Williams KM, Wolff D, Cowen EW, et al. National Institutes of Health consensus development project on criteria for clinical trials in chronic graft-versus-host disease: I. The 2014 diagnosis and staging working group report. Biol Blood Marrow Transplant 2015;21:389-401.e1.
3. Chi AK, Soubani AO, White AC, Miller KB. An update on pulmonary complications of hematopoietic stem cell transplantation. Chest 2013;144:1913-22.
4. Soubani AO, Kingah P, Alshabani K, Muma G, Haq A. Lung transplantation following hematopoietic stem cell transplantation: report of two cases and systematic review of literature. Clin Transplant 2014;28:776-82.
5. Sakaida E, Nakaseko C, Harima A, Yokota A, Cho R, Saito Y, et al. Late-onset noninfectious pulmonary complications after allogeneic stem cell transplantation are significantly associated with chronic graft-versus-host disease and with the graft-versus-leukemia effect. Blood 2003;102:4236-42.
6. Au BK, Au MA, Chien JW. Bronchiolitis obliterans syndrome epidemiology after allogeneic hematopoietic cell transplantation. Biol Blood Marrow Transplant 2011;17:1072-8.
7. Arai S, Arora M, Wang T, Spellman SR, He W, Couriel DR, et al. Increasing incidence of chronic graft-versus-host disease in allogeneic transplantation: a report from the Center for International Blood and Marrow Transplant Research. Biol Blood Marrow Transplant 2015;21:266-74.
8. Calhoon JH, Levine S, Anzueto A, Bryan CL, Trinkle JK. Lung transplantation in a patient with a prior bone marrow transplant. Chest 1992;102:948.
9. Holm AM, Riise GC, Hansson L, Brinch L, Bjørtuft O, Iversen M, et al. Lung transplantation for bronchiolitis obliterans syndrome after allo-SCT. Bone Marrow Transplant 2013;48:703-7.
10. Redel-Montero J, Bujalance-Cabrera C, Vaquero-Barrios JM, Santos-Luna F, Arenas-De Larriva M, Moreno-Casado P, et al. Lung transplantation for bronchiolitis obliterans after allogenic bone marrow transplantation. Transplant Proc 2010;42:3023-5.
11. Gao F, Chen J, Wei D, Wu B, Zhou M. Lung transplantation for bronchiolitis obliterans syndrome after allogenic hematopoietic stem cell transplantation. Front Med 2018;12:224-8.
12. Vogl UM, Nagayama K, Bojic M, Hoda MA, Klepetko W, Jaksch P, et al. Lung transplantation for bronchiolitis obliterans after allogeneic hematopoietic stem cell transplantation: a single-center experience. Transplantation 2013;95:623-8.
13. Cheng GS, Edelman JD, Madtes DK, Martin PJ, Flowers ME. Outcomes of lung transplantation after allogeneic hematopoietic stem cell transplantation. Biol Blood Marrow Transplant 2014;20:1169-75.
14. Snell GI, Yusen RD, Weill D, Strueber M, Garrity E, Reed A, et al.

https://doi.org/10.3349/ymj.2024.0475

Report of the ISHLT Working Group on Primary Lung Graft Dysfunction, part I: definition and grading-A 2016 Consensus Group statement of the International Society for Heart and Lung Transplantation. J Heart Lung Transplant 2017;36:1097-103.
15. Chambers DC, Perch M, Zuckermann A, Cherikh WS, Harhay MO, Hayes D Jr, et al. The International Thoracic Organ Transplant Registry of the International Society for Heart and Lung Transplantation: thirty-eighth adult lung transplantation report - 2021; focus on recipient characteristics. J Heart Lung Transplant 2021;40:1060-72.
16. Bensinger WI, Martin PJ, Storer B, Clift R, Forman SJ, Negrin R, et al. Transplantation of bone marrow as compared with peripheral-blood cells from HLA-identical relatives in patients with hematologic cancers. N Engl J Med 2001;344:175-81.
17. Bensinger W; Stem Cell Trialists' Collaborative Group. Individual patient data meta-analysis of allogeneic peripheral blood stem cell transplant vs bone marrow transplant in the management of hematological malignancies: indirect assessment of the effect of day 11 methotrexate administration. Bone Marrow Transplant 2006;38:539-46.
18. Nakaseko C, Ozawa S, Sakaida E, Sakai M, Kanda Y, Oshima K, et al. Incidence, risk factors and outcomes of bronchiolitis obliterans after allogeneic stem cell transplantation. Int J Hematol 2011;93:375-82.
19. Orens JB, Estenne M, Arcasoy S, Conte JV, Corris P, Egan JJ, et al. International guidelines for the selection of lung transplant candidates: 2006 update—a consensus report from the Pulmonary Scientific Council of the International Society for Heart and Lung Transplantation. J Heart Lung Transplant 2006;25:745-55.
20. Jeong YH, Kim DK, Choi S. Current status of lung transplantation in Korea. Curr Chall Thorac Surg 2022;4:4.
21. Hamilton BCS, Dincheva GR, Matthay MA, Hays S, Singer JP, Brzezinski M, et al. Improved survival after lung transplantation for adults requiring preoperative invasive mechanical ventilation: a national cohort study. J Thorac Cardiovasc Surg 2020;160:1385-95.e6.
22. Upala S, Panichsillapakit T, Wijarnpreecha K, Jaruvongvanich V, Sanguankeo A. Underweight and obesity increase the risk of mortality after lung transplantation: a systematic review and meta-analysis. Transpl Int 2016;29:285-96.
23. Halpern AL, Boshier PR, White AM, Houk AK, Helmkamp L, Mitchell JD, et al. A comparison of frailty measures at listing to predict outcomes after lung transplantation. Ann Thorac Surg 2020;109:233-40.
24. Jung HS, Lee JG, Yu WS, Lee CY, Haam SJ, Paik HC. Early outcomes of lung transplantation for bronchiolitis obliterans syndrome after allogeneic haematopoietic stem cell transplantation: a single-centre experience. Interact Cardiovasc Thorac Surg 2016;23:914-8.
25. Christie JD, Edwards LB, Kucheryavaya AY, Benden C, Dipchand AI, Dobbels F, et al. The registry of the International Society for Heart and Lung Transplantation: 29th adult lung and heart-lung transplant report—2012. J Heart Lung Transplant 2012;31:1073-86.